

REMOTELY CONTROLLABLE SYSTEM FOR POSITIONING AN
OBSERVATION/INTERVENTION DEVICE ON A PATIENT

The present invention relates to a remotely control-
lable system for positioning a mobile observation and/or inter-
vention system on a patient. It applies, for example, to medical
analysis systems, such as endoscopic or echographic systems or
5 to simple invasive devices such as a puncture needle. It will
more specifically be described in the context of the use of an
echographic probe (remote echography).

Echography is a very advantageous imaging modality,
because of its lightness, harmlessness, and its richness in
10 morphological and functional information. Its implementation
requires a particular specialization. Several clinical
situations would require for the examination to be performed by
telemedicine means.

The simplest solution, used in some telemedicine
15 operations, is for a local operator to put himself in vocal and
possibly video connection with a distant expert doctor. It could
then be devised for the nurse or even for the patient himself to
handle an echographic probe and for the distant expert to guide
him and draw a diagnosis therefrom. Such resorting to a distant
20 expert is used in several medical situations but applies with
difficulty to echography. Indeed, in echography, the performing

and interpretation of the examination are intimately connected. Only the operator, who has controlled the way in which the echographic probe has been displaced on the patient's body, has all the information useful for the interpretation. This feature
5 makes remote echography operations difficult. The local operator must already be relatively well trained, and the remote expert must be able to precisely indicate to him the probe displacements to be performed. Now, such displacements imply 6 degrees of freedom (three translations and three rotations). It
10 can be understood that the expression by the remote expert of the displacement orders in vocal form, and even more their execution by the local operator, may be difficult.

To overcome the disadvantages of the above-mentioned simple remote echography, it would be necessary to enable the
15 distant expert to take control of the displacement of the echographic probe, for example, by controlling a probe assembled on a remote-controlled robot. Such systems using robotics are used in medicine and especially in surgery. For this purpose, robotic architectures of master-slave type are typically used, in which
20 a remote operator has a stress feedback system which enables him to displace a virtual object according to n degrees of freedom and in which a slave system placed close to the patient reproduces the master's motions while said master can feel a resistance to its motion.

25 In the conventional approach, the master and the slave execute exactly the same motions, the slave being linked to a referential with respect to which the patient's position must be located. The mechanical constraints to which the slave is submitted must remain within limits compatible with the
30 possibilities of synthesis of a stress feedback by the master. Besides, the used mechanical architectures use rigid and relatively heavy structures, even when the useful load has a weight smaller than 10 N. It is thus imperative to design high-performance security systems, able to forbid uncontrolled
35 motions of the robot, which would be likely to harm the patient or the medical and surgical team surrounding him.

Fig. 1 shows a very simplified side view of a patient 1 lying on a table 3 for a conventionally remotely controlled echographic examination. An echographic probe 5 is arranged to contact the patient, for example, his abdomen, by an articulated and remote controlled robot arm system 7. Such a system implies a heavy computer architecture to ensure the control and stress feedback. It should be noted that the slave (supporting the echographic probe) contacts the human body, which exerts against it variable and widely unpredictable pressures. This requires, if the system is desired to securely operate, implementing an extremely complex system. Due to all these constraints, the slave is a costly system.

The dilemma thus currently is the following: to use a local operator guided by a distant expert, which appears to be poorly adapted, or to use a robotic system, having a particularly heavy and expensive mechanical structure and associated computer system.

More generally, the above problem, that is, to provide a low-cost secure remotely controlled positioning system, is posed in many other cases falling or not within the medical field. In the medical field, a problem of the same type is posed, for example, for the remote control in orientation and in position of an endoscope or a puncture needle.

Operations performed under endoscopy grow in number. They require introduction of various tools of generally cylindrical shape through the skin. The number of these tools may be such that the operator is disturbed by its assistants which maintain them for him in an adequate position. For this and other reasons, various systems have been developed to bear and position tools penetrating into the human body upon interventions under endoscopy. These systems are "conventional" robots, which are fastened to the operating table or to the ground, and which displace the tools that they support to the coordinates which are communicated thereto by various interfaces with the user, or even, in some cases, by control of the images observed by the endoscope. Such systems remain heavy and require specific adaptation to take into account security problems

linked to the use of relatively rigid systems supporting surgical instruments.

The puncture of various organs of the human body is a widely used method to sharpen a diagnosis (sampling of material
5 for microscopic analyses, measurement of various physical, and especially electric characteristics ...), or for therapy (physical, mechanical, chemical, electric destruction ...). In many cases, the puncture is performed under control of imaging means (radio, echography, scanner, MRI...). It may be
10 advantageous to robotize the positioning of the puncture needle, which opens up the way to the automated implementation of the puncture gesture in several clinical situations, among which, in particular:

- a physically limited access to the patient (scanner, MRI...),
- 15 - the need to perform the gesture rapidly, and
- the need to perform the gesture from a distance.

Again, existing remotely controlled robotization and positioning systems are too heavy to enable easy generalization of this type of application.

20 Thus, an object of the present invention is to provide a remotely controlled system for positioning a diagnosis or therapeutic device which is relatively simple.

Another object of the present invention is to provide such a system which has a low cost while avoiding any risk for
25 the patient and the people around him.

Another object of the present invention is to provide such a system in which it can be passed from a remote control to a local handling of the controlled device.

Another object of the present invention is to provide
30 a specific remotely controllable device for displacing an object.

To achieve these objects, the present invention generally provides a remotely controllable system for positioning a useful load, in which:

- 35 - the components exhibit compliance features, that is, are likely to reversibly deform under the effect of moderate mechanical constraints, external to the system (this implies in

particular that the system be not only formed of rigid arms);
and

5 - the motions tend to reproduce the order of a remote operator, but taking account of the system environment, especially of the topography of the site in which is placed the device having a remotely controlled displacement (light control), and without it being necessary to know at any time the geometric characteristics of the various system components.

10 Such a system thus differs from conventional robots, most of the components of which are rigid, and in which a compliance can only be obtained by specific characteristics of the joints between the rigid elements, and the control of which implies as fine a knowledge as possible of the geometric characteristics of the robot, a coordinate changer typically enabling
15 passing from the "articular" coordinates of the robot to the cartesian coordinates, by means of a model of the robot.

 The "compliance" and "light control" properties are particularly well adapted to medicine applications, when diagnosis or therapeutic tools are desired to be displaced on the
20 human body. The compliance enables having the system and the tools that it bears directly contact the patient (whose body may even be used to help supporting the system and its useful load). The light control cannot be a handicap; indeed, the precise knowledge of the position of the system and of the controlled
25 device in a referential external to the patient (provided by the "conventional" control) teaches much less than the knowledge of the position of the useful load with respect to the anatomic or therapeutic targets of the human body. Now, this relative position information can be provided by the controlled device
30 itself, by various sensors, or by learning.

 More specifically, the present invention provides a remotely controllable system for positioning on a patient an observation and/or intervention device including a frame to which the device is bound with a number of degrees of freedom;
35 flexible connection means, each of which is arranged between the frame and a point attached to the patient's support or to the patient himself; remotely controlled means for modifying the

length/tension of the binding means; and means for remotely observing the device behavior.

According to an embodiment of the present invention, each of the flexible binding means is of cable, thread, or strap type.

According to an embodiment of the present invention, each of the flexible binding means is resilient.

According to an embodiment of the present invention, the remotely controlled means include winder motors.

According to an embodiment of the present invention, the remotely controlled means include artificial muscles.

According to an embodiment of the present invention, the connection between the frame and the device is ensured by remotely controlled flexible binding means.

According to an embodiment of the present invention, the device is an echographic probe, and said remote observation means enable observation of the echographic image.

According to an embodiment of the present invention, the device is an endoscope, and the remote observation means enable observation of the endoscopic image.

According to an embodiment of the present invention, the device is a needle holder, and the remote observation means enable observation of an image of scanner, MRI, ... type.

According to an embodiment of the present invention, the link between the patient and the distant remote-control central station includes an audio link.

The foregoing objects, features and advantages of the present invention, will be discussed in detail in the following non-limiting description of specific embodiments in connection with the accompanying drawings.

Fig. 1 shows a remote echography system using conventional robotic techniques;

Fig. 2 is a very simplified top view of a remote echography system according to the present invention;

Fig. 3 is a partial view of an example of a supporting frame of an echographic probe usable according to the present invention; and

Fig. 4 is a partial view of another example of an echographic probe-supporting frame usable according to the present invention.

The present invention will first be more specifically described in the context of the use of an echographic probe (remote echography).

The present invention is based on an analysis of the actual needs of a remote echography operation. The distant expert must be able to:

- 10 - have a general vision of the scene, and dialog with the patient and with the local staff,
- control the acquisition parameters of the echograph,
- visualize the echographic images,
- indicate, by displacing a virtual probe, the direc-
- 15 tion of the desired displacements of the real probe (six degrees of freedom),
- displace the real probe according to these indications,
- control on the echographic images the way in which
- 20 the displacement orders are really taken into account,
- adapt the orders to the way in which they are executed and to needs,
- possibly have, from the virtual probe, an information feedback concerning the pressure exerted by the real
- 25 probe on the patient.

The patient or a local operator must also be able to:

- initialize the probe displacement system,
- interrupt the probe displacement if it becomes painful (too high a pressure, for example),
- 30 - give back the control to the expert after such an interruption; and
- possibly manually displace the probe, according to the expert's vocal indications, to face specific situations.

The applicant has found that these requirements could be better fulfilled with a remotely controlled system having a compliant structure and a light control than with a master-slave type robot of rigid structure such as previously described.

Further, the use of a flexible or compliant remote displacement structure avoids forbidding any motion to the patient during an analysis, which, in the case of an echography, may be relatively long.

5 According to an aspect of the present invention, the applicant has noted that, in fact, when an echography is performed, the expert has a sufficient indication of the motions that the probe has performed and that it desires it to perform from the echographic image that he receives. For him to know
10 exactly the probe positioning with respect to the patient matters little. It is enough that, from a given positioning, he can perform a displacement roughly in a desired direction (translation, rotation) and that, after each incremental displacement, he can decide whether he desires to continue the
15 displacement in the same direction or move in another direction to better see what is desired to be observed. Thus, the present invention provides suppression of any rigid connection between the probe and the patient's support. Further, the echographic probe sustentation or suspension function is suppressed. The
20 system displaces the probe on the patient's body while said probe rests on said body.

Fig. 2 shows an embodiment of the present invention. A patient 1 lying on a table 3 is considered again. Echographic probe 5 moves along with a frame 11 laid on the patient's body.
25 According to the present invention, various flexible mechanical means such as straps, threads, cables, or the like are provided to have frame 11 of a probe slide on the patient's body around a selected location. For example, in the embodiment shown, frame 11 is attached to four straps 12, 13, 14, and 15, the second
30 ends of which are attached at points 16, 17, 18, and 19. Points 16 to 19 may for example be binding points attached to table 3. They also may be binding points attached to straps respectively arranged around the patient's arms and thighs. It should be understood that by providing at the level of the connection
35 between each of the straps and the frame a winder motor, the displacement of frame 11 around an initially selected area and its pressure on the body can be remotely controlled. A

releasable means will preferably be provided to enable manually positioning frame 11 in an initial position.

As shown in Fig. 3, frame 11 may be a package in which echographic probe 21 is mobile in a remotely controllable way. For example, the probe is bound to an arm 22 mobile in the package perpendicularly thereto, to apply a higher or lower pressure between the probe and the patient. Arm 22 will for example be mobile in rotation around its axis (direction α) and with respect to this axis around a joint 23 (direction β). Conventionally, more or fewer degrees of freedom may be provided.

In the embodiment of Fig. 4, frame 11 is a simple plate on which is assembled, for example by a ball joint system 31, an echographic probe 30. The probe body may be displaced and oriented with respect to the plate by means of an assembly of automatic actuators 33, 34, 35. The pneumatic actuators are for example inflatable tubes currently called "artificial muscles", the length of which decreases when they receive a gas under pressure.

Although this is not described in detail herein, means for controlling the various motors and other previously-described remotely controllable means with the displacements of a master unit handled by a remote operator communicating with the drive system just described by any means such as a radio link, an optical cable link, or other, are known in the art.

Various modes of action on the controlled device may be provided.

The device displacement may be completely automated and correspond to a predetermined strategy. This strategy for example aims at fulfilling a criterion of complete scanning by the echographic probe of a selected anatomic volume.

The displacement of the device may involve an expert who uses the images generated by the device or physical information characterizing the device behavior to adapt his medical strategy. The physical information may especially be:

- position information, provided by video cameras, a three-dimensional locator, or length encoders of the flexible binding means,

5 - physiological signals generated by the device or by sensors coupled to the device, or

- measurements of the pressure or of the mechanical stress exerted by the environment on the system.

To ensure the patient's security, and avoid for excessive pressures to be applied to him by the probe or its frame, 10 it may be provided for straps 12-15 to have a certain resilience, or to be bound by rupture systems. Any other passive security system may be provided to avoid for the slave to exert on the patient any force or pressure beyond predetermined limits. Similarly, the elements of displacement between the 15 probe and the frame may be flexible, and possibly resilient.

The system of Fig. 2 is an example only of implementation of the present invention. The basic aspect of the present invention is that it provides a system enabling remote control of the sliding and orientation of a therapeutic or diagnosis 20 device on the human body. Many alternative embodiments may be provided to ensure this function. For example, the straps may be replaced by any other "thread" system possibly driven by "artificial muscles" (inflatable tubes tightened in braids exerting variable tractions under the effect of pressure variations generated by valves likely to be controlled by 25 computer means), or by rigid cradle and spring systems. Of course, it will further have to be provided for the various system components in contact with the skin to slide thereon. The straps may for example, in the case of the specific described embodiment, be soaked with an echographic gel. 30

It is particularly simple, for a local operator or for the patient himself, to rapidly release the system by means of an easily accessible control to interrupt the remotely controlled displacement if the system should become painful, or 35 to displace the frame as selected and required by the distant expert to whom the patient is linked by an audio and preferably video link.

An application to an endoscopic system will be implemented in an analogous manner, the information feedback between the endoscope and the remote expert corresponding to the very image provided by the endoscopic camera.

5 In the context of an application such as the placing of a puncture needle, the image feedback to the distant expert may come from one or several video cameras observing the general scene, from a tri-dimensional locator able to follow the position or the orientation of the needle, or from a specific
10 imaging system (X-rays, scanner, MRI...).